MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

ETN3136 – DIGITAL COMMUNICATIONS
(TE & MCE)

17 OCTOBER 2016
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 10 pages (including the cover page) with 4 Questions only.

2. Attempt all of the **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Figure Q1.1 shows that a signal $x(t)$ is transmitted over a channel and the channel output is $r(t)$. Is the transmission distortionless? Justify your answer.

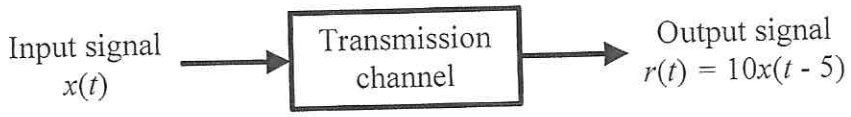

Figure Q1.1

[4 marks]

(b) Explain the Nyquist sampling theorem and the aliasing phenomenon.

[5 marks]

(c) A signal $m(t)=\cos(1000t)+2\cos(2000t)+3\cos(4000t)$ is to be uniformly sampled for digital transmission.

(i) Calculate the minimum sampling frequency for $m(t)$ required to avoid aliasing.

[3 marks]

(ii) Determine the maximum permissible time interval between sample values that will ensure perfect signal reproduction.

[2 marks]

(iii) The signal $m(t)$ is sampled at a rate of 10 times higher than the Nyquist rate and converted to binary signal using pulse code modulation (PCM). Compute the bit rate of the encoded signal if uniform quantization with 16 levels of uniform quantization is used without compression.

[3 marks]

Continued .....

Question 1

(d) The spectrum of an analogue signal is shown in Figure Q1.2. The analogue signal is sampled using natural sampling at a sampling rate of 10 kHz with pulse width of $\tau = 50\ \mu s$.

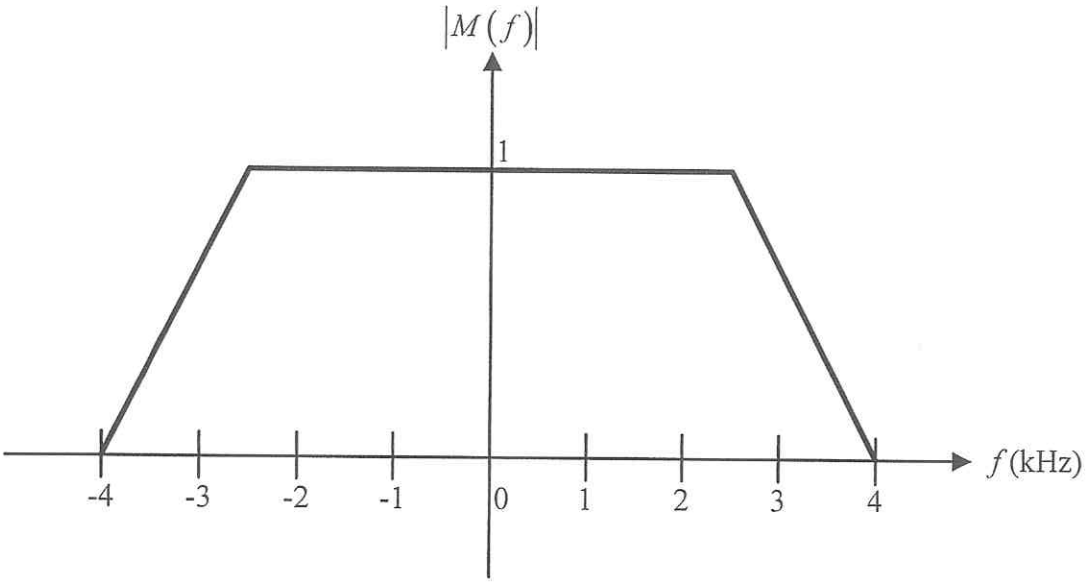

Figure Q1.2

(i) Does aliasing (spectral overlapping) occur in this natural sampling process? Justify your answer.

[2 marks]

(ii) Compute the first-null bandwidth of the naturally sampled signal.

[3 marks]

(iii) Plot the magnitude spectrum of the naturally sampled signal.

[3 marks]

Question 2

(a) For a binary data sequence of 1101001, sketch the transmitted waveform for the following line coding techniques:

(i) Polar nonreturn-to-zero (NRZ).

[2 marks]

(ii) Manchester NRZ.

[2 marks]

Continued .....

Question 2

(b) Delta modulation (DM) is a method of converting analog signals to a string of binary digits that requires much simpler circuitry than PCM. Delta modulation is subject to slope overload distortion and granular noise.

(i) With the aid of diagram, briefly explain the concept of slope overload distortion and granular noise.

[6 marks]

(ii) Consider a sine wave of frequency f_m and amplitude A_m applied to a delta modulator of step size Δ. Prove that the slope overload distortion will occur if $\Delta < 2\pi A_m f_m T_s$, where T_s is the sampling period.

[5 marks]

(iii) A DM system is designed to operate at 3 times the Nyquist rate for a signal with a 3 kHz bandwidth. If the input signal is a 1 kHz sinuisoid with peak amplitude of 716.2mV, determine the minimum quantizing step size required to avoid slope overload distortion.

[4 marks]

(c) With the aid of a suitable diagram, discuss how intersymbol interference (ISI) arises in digital communication systems and explain its effect on the system's performance.

[6 marks]

Question 3

(a) Equalization is a technique used to mitigate intersymbol interference (ISI).

(i) Describe briefly the working principle of the maximum likelihood sequence estimation (MLSE) equalizer.

[2 marks]

(ii) Give two examples of linear equalizer.

[2 marks]

Continued .....

Question 3

(b) An analogue signal is converted to binary signal using pulse code modulation (PCM) with a sampling rate of 8000 samples/s and 7-bit (128 levels) quantization. The resultant binary stream is then transmitted using raised-cosine roll-off shaping for each binary pulse. The roll-off factor is 20%.

(i) Calculate the bit rate of the PCM signal.

[2 marks]

(ii) Calculate the baseband bandwidth (bandwidth of the PCM signal) if binary amplitude shift keying (ASK) is used for transmission.

[2 marks]

(iii) Compute the minimum transmission bandwidth required to avoid intersymbol interference (ISI) if binary ASK is used for transmission.

[3 marks]

(iv) Repeat Question 3(b)(iii) if binary phase shift keying (BPSK) is used for transmission.

[3 marks]

(v) Repeat Question 3(b)(iii) if 16-state quadrature amplitude modulation (QAM) is used for transmission.

[3 marks]

(c) Discuss briefly the differences between coherent demodulation and noncoherent demodulation.

[3 marks]

(d) With the aid of a suitable diagram, explain how intersymbol interference (ISI) can be mitigated using an orthogonal frequency division multiplexing (OFDM) modulation scheme.

[5 marks]

Continued .....

Question 4

(a) A digital communication system operates at a signal-to-noise ratio (SNR) of 28dB and utilizes a bandwidth of 4000Hz.

(i) Can the system achieve error free transmission at a bit rate of 50kbps? Justify your answer.

[4 marks]

(ii) Determine the minimum SNR (in decibels) required for error free transmission if the intended transmission rate is 30kbps.

[4 marks]

(b) (i) Explain the main function of a matched filter at the receiver.

[2 marks]

(ii) Consider the message signal waveform shown in Figure Q4.1. Sketch the impulse response (in the time domain) of a matched filter to be used.

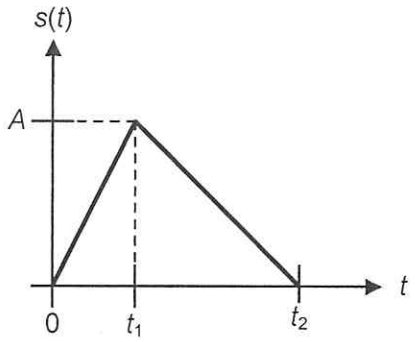

Figure Q4.1

[5 marks]

(c) A direct-sequence binary phase-shift keying (DS/BPSK) spread spectrum system is required to achieve an average probability of symbol error $P_e = \frac{1}{2}\left[1 - erf\left(\sqrt{\frac{E_b}{N_0}}\right)\right]$ that does not exceed 10^{-5} in the presence of externally generated interfering signals, where E_b is the energy per bit and N_0 is the noise spectral density. The system uses a feedback shift register of length m = 19 to generate pseudo-noise (PN) sequence. The chip rate is 10^8 chips per second. Calculate the following parameters:

(i) Processing gain in decibels.

[3 marks]

Continued .....

Question 4

(c)

(ii) Anti-jam margin in decibels. The anti-jam margin is given as $G(\text{dB}) - \frac{E_b}{N_0}(\text{dB})$, where $G(\text{dB})$ is the processing gain in decibels and $\frac{E_b}{N_0}(\text{dB})$ is $\frac{E_b}{N_0}$ in decibels.

[4 marks]

(iii) Chip duration of the PN sequence.

[1.5 marks]

(iv) PN sequence period.

[1.5 marks]

Continued .....

Appendix 1: Table of Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_o) \Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t} \Leftrightarrow X(f-f_o)$
Time Convolution	$x_1(t) * x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f) * X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tilde{t})d\tilde{t} \Leftrightarrow \frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$

Continued .....

Appendix II

Error function erf $x = (2/\sqrt{\pi})\int_0^x e^{-x^2} dx$

x	erf x	x	erf x	x	erf x
0.00	0.00000	1.05	0.86244	2.10	0.99702
0.05	0.05637	1.10	0.88021	2.15	0.99764
0.10	0.11246	1.15	0.89612	2.20	0.99814
0.15	0.16800	1.20	0.91031	2.25	0.99854
0.20	0.22270	1.25	0.92290	2.30	0.99886
0.25	0.27633	1.30	0.93401	2.35	0.99911
0.30	0.32863	1.35	0.94376	2.40	0.99931
0.35	0.37938	1.40	0.95229	2.45	0.99947
0.40	0.42839	1.45	0.95970	2.50	0.99959
0.45	0.47548	1.50	0.96611	2.6	0.99976
0.50	0.52050	1.55	0.97162	2.7	0.99987
0.55	0.56332	1.60	0.97635	2.8	0.99992
0.60	0.60386	1.65	0.98038	2.9	0.99996
0.65	0.64203	1.70	0.98379	3.0	0.99998
0.70	0.67780	1.75	0.98667		
0.75	0.71116	1.80	0.98909		
0.80	0.74210	1.85	0.99111		
0.85	0.77067	1.90	0.99279		
0.90	0.79691	1.95	0.99418		
0.95	0.82089	2.00	0.99532		
1.00	0.84270	2.05	0.99626		

Continued .....

Appendix III

Tabulated values of Q-function

The Q Function (Gaussian Distribution with $\mu = 0$ and $\sigma = 1$)

$$Q(a) = \int_a^\infty \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx \qquad Q(a) \cong \frac{1}{a\sqrt{2\pi}} e^{\frac{-a^2}{2}} \text{ for } a \geq 3$$

	3rd Significant Digit									
a	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2297	0.2266	0.2236	0.2207	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1094	0.1075	0.1057	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

$Q(a)$	a
10^{-4}	3.73
5×10^{-5}	3.90
10^{-5}	4.27
5×10^{-6}	4.43

$Q(a)$	a
10^{-6}	4.76
10^{-7}	5.20
10^{-8}	5.61
10^{-9}	6.00

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